CLAIMS

We claim:

1. A method of noninvasively applying an ultrasonic excitation signal from at least one transducer to human tissue in vivo for therapeutic applications, comprising:

acoustically coupling a modal converter to a tissue surface, wherein the modal converter comprises a top surface, a bottom surface, and a plurality of side surfaces positioned at angles relative to the bottom surface such that the at least one transducer is acoustically coupled to one of the plurality of side surfaces and can emit an acoustic wave that reflects at an interface and, after reflection, travels parallel to and along the interface; and

emitting an acoustic wave from the at least one transducer acoustically coupled to the modal converter at an angle relative to the bottom surface of the modal converter, such that the acoustic wave emitted from the at least one transducer reflects upon striking the interface and after reflection travels parallel to and along the interface.

2. The method of claim 1, further comprising generating an excitation signal and transmitting the excitation signal to the at least one transducer.

3. The method of claim 1, further comprising controlling the spatial and temporal distribution of acoustic energy from the at least one transducer using a system controller.

4. The method of claim 3, wherein using the system controller further comprises

using a programmable microprocessor.

5. The method of claim 1, further comprising generating longitudinal waves that propagate substantially normal to the tissue surface, the waves being generated from at least one transducer positioned on the top surface of the modal converter.

6. The method of claim 1, wherein emitting an acoustic wave toward the interface further comprises emitting the acoustic wave toward an interface between a skin tissue surface and the modal converter.

7. The method of claim 6, wherein emitting the acoustic wave toward an interface between a skin tissue surface and the modal converter further comprises emitting the acoustic wave at a first critical angle relative to the bottom surface of the modal converter such that the acoustic wave converts partially into a longitudinal wave traveling parallel to and along the skin tissue surface, and converts partially into a shear wave traveling at a refraction angle, θ_{SV}, after incidence at the interface between the skin tissue surface and the modal converter, wherein $\theta_{SV} = \sin^{-1}\{(1-2\nu)/2(1-\nu)\}^{1/2}$, wherein ν represents Poisson's ratio for soft tissue and sv refers to the vertical component of the shear wave.

8. The method of claim 1, wherein emitting the acoustic wave toward the interface further comprises emitting the acoustic wave toward an interface between bone

tissue and surrounding soft tissue.

9. The method of claim 8, wherein emitting the acoustic wave toward an interface between bone tissue and surrounding soft tissue further comprises emitting the acoustic wave at a first critical angle relative to the bottom surface of the modal converter such that the acoustic wave converts partially into a longitudinal wave traveling parallel to and along the interface between the surrounding soft tissue and the bone tissue, and converts partially into a shear wave traveling at a refraction angle, θ_{SV}, after incidence at the interface between the surrounding soft tissue and the bone tissue, wherein $\theta_{SV} = \sin^{-1}\{(1-2\nu)/2(1-\nu)\}^{1/2}$, wherein ν represents Poisson's ratio for bone tissue and sv refers to the vertical component of the shear wave.

10. The method of claim 9, further comprising emitting an acoustic wave from the at least one transducer at a second critical angle relative to the bottom surface of the modal converter such that the acoustic wave reflects and travels as an acoustic shear wave parallel to and along the interface between the surrounding soft tissue and bone tissue after incidence at the interface between the surrounding soft tissue and bone tissue.

11. The method of claim 10, further comprising emitting an acoustic wave from the at least one transducer at the second critical angle that converts totally into an acoustic shear wave traveling parallel to and along the bone tissue surface.

12. The method of claim 1, wherein acoustically coupling a modal converter to a tissue surface further comprises acoustically coupling a modal converter comprising a material having an acoustic impedance comparable to an acoustic impedance for human soft tissue.

13. The method of claim 1, wherein acoustically coupling a modal converter to a tissue surface further comprises acoustically coupling a modal converter comprising a material having a longitudinal velocity less than a longitudinal velocity for human soft tissue.

14. The method of claim 1, wherein acoustically coupling a modal converter to a tissue surface further comprises acoustically coupling a modal converter comprising a material having a longitudinal velocity less than a longitudinal velocity for bone tissue.

15. The method of claim 1, wherein acoustically coupling a modal converter to a tissue surface further comprises acoustically coupling a modal converter comprising thermoplastics, thermosets, elastomers or combinations thereof.

16. The method of claim 15, wherein acoustically coupling a modal converter to a tissue surface further comprises acoustically coupling a modal converter comprising ethyl vinyl acetate, ecothane, polyurethane, silicone or combinations thereof.

17. The method of claim 1, wherein acoustically coupling a modal converter to a

tissue surface further comprises acoustically coupling a modal converter comprising a coupling material having an acoustic impedance comparable to an acoustic impedance for human soft tissue.

18. The method of claim 1, wherein the emitting of acoustic waves from the at least one transducer occurs multiple times during a time period comprising a dosage period, wherein the dosage period is between about 1 and about 60 minutes.

19. The method of claim 2, wherein generating an excitation signal further comprises generating an excitation signal that is a modulated pulsed sine wave.

20. The method of claim 19, wherein generating an excitation signal further comprises generating an excitation signal that is amplitude modulated.

21. The method of claim 19, wherein generating an excitation signal further comprises generating an excitation signal that is phase modulated.

22. The method of claim 21, wherein generating an excitation signal further comprises generating an excitation signal that is within the range from a delayed linear (CW) to a logarithmic (hyperbolic FM) variation with time, based on a power series representation of a frequency versus time curve as defined by $f(t) = \alpha_o + \alpha_1 t + \alpha_2 t^2 + \alpha_3 t^3 + \cdots$, wherein the set of constants, α, characterize a particular modulation system.

23. The method of claim 19, wherein generating an excitation signal further comprises generating an excitation signal comprising a carrier frequency, a pulsewidth, a pulse repetition frequency, and a spatial-average temporal-average intensity.

24. The method of claim 23, wherein generating an excitation signal further comprises generating an excitation signal comprising a carrier frequency that is within the range of 10 kHz to 10 MHz for the at least one transducer.

25. The method of claim 23, wherein generating an excitation signal further comprises generating an excitation signal comprising a pulsewidth that is within the range of 100 microseconds to 100 milliseconds for the at least one transducer.

26. The method of claim 23, wherein generating an excitation signal further comprises generating an excitation signal comprising a pulse repetition frequency that is within the range of 1 Hz to 10,000 Hz for the at least one transducer.

27. The method of claim 23, wherein generating an excitation signal further comprises generating an excitation signal comprising a spatial-average temporal-average intensity that is within the range of 5 mW/cm^2 to 500 mW/cm^2 for the at least one transducer.

28. An apparatus for noninvasively applying an ultrasound excitation signal from at least one transducer to human tissue in vivo for therapeutic applications, comprising:

a modal converter including a top surface, a plurality of side surfaces, a bottom surface, and at least one transducer, wherein the plurality of side surfaces are positioned at angles relative to the bottom surface and wherein the at least one transducer is acoustically coupled with one of the plurality of sides of the modal converter and positioned at an angle relative to the bottom surface such that an acoustic wave emitted from the at least one transducer reflects upon striking an interface and travels parallel to and along the interface.

29. The apparatus of claim 28, further comprising a system controller for controlling the spatial and temporal distribution of the acoustic wave from the at least one transducer.

30. The apparatus of claim 28, further comprising a system generator for generating and transmitting an excitation signal to the at least one transducer.

31. The method of claim 29, wherein the system controller is a programmable microprocessor.

32. The apparatus of claim 28, wherein said modal converter further comprises at least one transducer positioned on the top surface of the modal converter for generating longitudinal waves normal to the skin tissue surface.

33. The apparatus of claim 28, wherein the interface comprises an interface

between a skin tissue surface and the modal converter.

34. The apparatus of claim 33, wherein the at least one transducer is positioned at a first critical angle relative to the bottom surface of the modal converter so that the at least one transducer may emit an acoustic wave that converts partially into a longitudinal wave traveling parallel to and along the skin tissue surface and converts partially into a shear wave traveling at a refraction angle, θ_{SV}, after incidence at the interface between the skin tissue surface and the modal converter, wherein $\theta_{SV} = \sin^{-1}\{(1-2\nu)/2(1-\nu)\}^{1/2}$, wherein ν represents Poisson's ratio for human soft tissue and sv refers to the vertical component of the shear wave.

35. The apparatus of claim 28, wherein the interface comprises an interface between surrounding soft tissue and bone tissue.

36. The apparatus of claim 34, wherein the at least one transducer is positioned at a first critical angle relative to the bottom surface of the modal converter so that the at least one transducer may emit an acoustic wave that converts partially into a longitudinal wave traveling parallel to and along the interface between surrounding soft tissue and bone tissue and converts partially into a shear wave traveling at a refraction angle, θ_{SV}, after incidence at the interface between surrounding soft tissue and bone tissue, wherein $\theta_{SV} = \text{sin-1}\{(1-2\nu)/2(1-\nu)\}^{1/2}$, wherein ν represents Poisson's ratio for human soft tissue and sv refers to the vertical component of the shear wave.

37. The apparatus of claim 28, wherein the at least one transducer is positioned at a second critical angle relative to the bottom surface of the modal converter such that the at least one transducer can emit an acoustic wave that reflects at the interface between the surrounding soft tissue and the bone tissue, and after incidence travels as an acoustic shear wave parallel to and along the interface between the surrounding soft tissue and the bone tissue.

38. The apparatus of claim 37, wherein the acoustic wave emitted from the at least one transducer at the second critical angle converts totally into an acoustic shear wave traveling parallel to and along the interface between the surrounding soft tissue and the bone tissue.

39. The apparatus of claim 28, wherein said modal converter comprises a material having an acoustic impedance comparable to an acoustic impedance for human soft tissue.

40. The apparatus of claim 28, wherein said modal converter comprises a material having a longitudinal velocity less than a longitudinal velocity for soft tissue.

41. The apparatus of claim 28, wherein said modal converter comprises a material having a longitudinal velocity less than a longitudinal velocity for bone tissue.

42. The apparatus of claim 28, wherein said modal converter comprises

thermoplastics, elastomers or combinations thereof.

43. The apparatus of claim 42, wherein said modal converter further comprises ethyl vinyl acetate, ecothane, polyurethane, silicone or combinations thereof.

44. A modal converter, comprising:

a top surface;

a substantially flat bottom surface;

a plurality of side surfaces capable of receiving at least one transducer and positioned at critical angles relative to the bottom surface such that an acoustic wave emitted from at least one transducer acoustically coupled to at least one side surface reflects upon striking an interface and travels parallel to and along the interface.

45. The modal converter of claim 44, wherein said modal converter further comprises a trapezoidal cross-section.

46. The modal converter of claim 44, wherein said top surface is substantially parallel to the bottom surface.

47. The modal converter of claim 44, wherein at least one side surface is positioned at a first critical angle relative to the bottom surface of the modal converter so that at least one transducer acoustically coupled to the at least one side surface can emit an acoustic wave that converts partially into a longitudinal wave traveling parallel to and

along a skin tissue surface and converts partially into a shear wave traveling at a refraction angle, θ_{SV}, after incidence at an interface between the skin tissue surface and the modal converter, wherein $\theta_{SV} = \sin^{-1}\{(1-2\nu)/2(1-\nu)\}^{1/2}$, wherein ν represents Poisson's ratio for human soft tissue and sv refers to the vertical component of the shear wave.

48. The modal converter of claim 44, wherein at least one side surface is positioned at a first critical angle relative to the bottom surface of the modal converter so that at least one transducer acoustically coupled to the at least one side surface can emit an acoustic wave that converts partially into a longitudinal wave traveling parallel to and along an interface between surrounding soft tissue and bone tissue and converts partially into a shear wave traveling at a refraction angle, θ_{SV}, after incidence at the interface between surrounding soft tissue and bone tissue, wherein $\theta_{SV} = \text{sin-1}\{(1-2\nu)/2(1-\nu)\}^{1/2}$, wherein ν represents Poisson's ratio for human soft tissue and sv refers to the vertical component of the shear wave.

49. The modal converter of claim 48, wherein at least one side surface is positioned at a second critical angle relative to the bottom surface of the modal converter such that at least one transducer acoustically coupled to the at least one side surface can emit an acoustic wave that reflects at the interface between the surrounding soft tissue and the bone tissue, and after incidence travels as an acoustic shear wave parallel to and along the interface between the surrounding soft tissue and the bone tissue.

50. The modal converter of claim 49, wherein the at least one side surface is positioned at the second critical angle relative to the bottom surface of the modal converter such that an acoustic wave emitted from the at least one transducer acoustically coupled to the at least one side surface converts totally into an acoustic shear wave traveling parallel to and along the interface between the surrounding soft tissue and the bone tissue.

51. The modal converter of claim 44, wherein said modal converter comprises a material having an acoustic impedance comparable to an acoustic impedance for human soft tissue.

52. The modal converter of claim 44, wherein said modal converter comprises a material having a longitudinal velocity less than a longitudinal velocity for soft tissue.

53. The modal converter of claim 44, wherein said modal converter comprises a material having a longitudinal velocity less than a longitudinal velocity for bone tissue.

54. The modal converter of claim 44, wherein said modal converter comprises thermoplastics, elastomers or combinations thereof.

55. The modal converter of claim 54, wherein said modal converter further comprises ethyl vinyl acetate, ecothane, polyurethane, silicone or combinations thereof.

56. A modal converter, comprising:

a top surface;

a substantially flat bottom surface;

a plurality of side surfaces; and

at least one cavity located within at least one side surface, wherein the at least one cavity is capable of receiving at least one transducer and wherein said at least one cavity comprises at least one flat surface capable being acoustically coupled to at least one transducer and positioned at a critical angle relative to the bottom surface such that an acoustic wave emitted from at least one transducer acoustically coupled to the at least one flat surface reflects upon striking an interface and travels parallel to and along the interface.

57. The modal converter of claim 56, wherein at least one flat surface is positioned at a first critical angle relative to the bottom surface of the modal converter so that at least one transducer acoustically coupled to the at least flat side surface can emit an acoustic wave that converts partially into a longitudinal wave traveling parallel to and along a skin tissue surface and converts partially into a shear wave traveling at a refraction angle, θ_{SV}, after incidence at an interface between the skin tissue surface and the modal converter, wherein $\theta_{SV} = \sin^{-1}\{(1-2\nu)/2(1-\nu)\}^{1/2}$, wherein ν represents Poisson's ratio for human soft tissue and sv refers to the vertical component of the shear wave.

58. The modal converter of claim 56, wherein at least one flat surface is positioned

at a first critical angle relative to the bottom surface of the modal converter so that at least one transducer acoustically coupled to the at least one flat surface can emit an acoustic wave that converts partially into a longitudinal wave traveling parallel to and along an interface between surrounding soft tissue and bone tissue and converts partially into a shear wave traveling at a refraction angle, θ_{SV}, after incidence at the interface between surrounding soft tissue and bone tissue, wherein $\theta_{SV} = \sin\text{-}1\{(1\text{-}2\nu)/2(1\text{-}\nu)\}^{1/2}$, wherein ν represents Poisson's ratio for human soft tissue and sv refers to the vertical component of the shear wave.

59. The modal converter of claim 58, wherein at least one flat surface is positioned at a second critical angle relative to the bottom surface of the modal converter such that at least one transducer acoustically coupled to the at least one flat surface can emit an acoustic wave that reflects at the interface between the surrounding soft tissue and the bone tissue, and after incidence travels as an acoustic shear wave parallel to and along the interface between the surrounding soft tissue and the bone tissue.

60. The modal converter of claim 59, wherein the at least one flat surface is positioned at the second critical angle relative to the bottom surface of the modal converter such that an acoustic wave emitted from the at least one transducer acoustically coupled to the at least one flat surface converts totally into an acoustic shear wave traveling parallel to and along the interface between the surrounding soft tissue and the bone tissue.

61. The modal converter of claim 56, wherein said modal converter comprises a material having an acoustic impedance comparable to an acoustic impedance for human soft tissue.

62. The modal converter of claim 56, wherein said modal converter comprises a material having a longitudinal velocity less than a longitudinal velocity for soft tissue.

63. The modal converter of claim 56, wherein said modal converter comprises a material having a longitudinal velocity less than a longitudinal velocity for bone tissue.

64. The modal converter of claim 56, wherein said modal converter comprises thermoplastics, elastomers or combinations thereof.

65. The modal converter of claim 64, wherein said modal converter further comprises ethyl vinyl acetate, ecothane, polyurethane, silicone or combinations thereof.

66. An apparatus for systemically administering therapeutic ultrasound to a patient, comprising:

a system controller for controlling the spatial and temporal distribution of acoustic energy from at least one transducer coupled to a modal wedge converter comprising, a top surface, a plurality of side surfaces, a bottom surface, and the at least one transducer, wherein the plurality of side surfaces are positioned at angles relative to the bottom surface and wherein the at least one transducer is acoustically coupled with one of the plurality of sides of the modal converter and positioned at an angle relative to the bottom surface such that an acoustic wave emitted from the at least one transducer reflects upon striking an interface and travels parallel to and along the interface.

67. The apparatus of claim 66, wherein the system controller is a programmable microprocessor.